KAJIAN FIZIK KESIHATAN NEGERI SELANGOR, WILAYAH PERSEKUTUAN KUALA LUMPUR DAN PUTRAJAYA

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Tesis ini dikemukakan
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ABSTRAK

Sinaran gama daratan adalah salah satu sinaran latar belakang utama dan penyinarannya disebabkan oleh keradioaktifan daratan. Kajian fizik kesihatan telah dilakukan untuk mendapatkan data dasar status keradioaktifan dan aras sinaran gama daratan (TGR) alam sekitar di negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya. Kajian mengemukakan metodologi pensampelan tinjauan kadar dos TGR, D_m dan kaedah model regresi statistik bagi meramalkan kadar dos TGR, D_p berdasarkan hubungan linear pengaruh latar belakang geologi, D_g dan jenis tanah, D_s terhadap jumlah kadar dos TGR. Tinjauan kadar dos TGR, D_m telah dilakukan menggunakan pengesan sintilasi NaI (Tl) Model 19 *Micro R Meter Ludlum*. Kaedah pensampelan telah digunakan untuk penentuan titik tinjauan, D_m berdasarkan maklumat daripada peta tinjauan udara, peta geologi dan peta tinjauan jenis tanah. Bagi tujuan kawalan kualiti kadar dos TGR sensitif, D_m pada aras alam sekitar, teknik statistik interpolasi kecerunan antara kadar dos terhitung, D_c dan D_m telah dilakukan dengan memanfaatkan data keradioaktifan pemancar sinar - γ ^{238}U, ^{232}Th dan ^{40}K dalam sampel tanah bagi mendapatkan faktor pembetulan, C_f. Analisis kepekatan keradioaktifan radionuklid ^{238}U, ^{232}Th dan ^{40}K dalam sampel tanah telah dilakukan menggunakan spektrometer gama sepaksi hiper - tulen germanium (HPGe). Berdasarkan maklumat dari pengkalan data dasar kadar dos TGR kajian terdahulu (1995 - 2013), sebanyak 9884 data kadar dos TGR dari pengkalan data dasar tersebut telah dianalisis taburan kenormalannya menggunakan ujian statistik Shapiro - Wilk, Kolgomorov - Smirnov dan ujian Levene. Analisis hipotesis statistik Welch ANOVA dan Tamhane T2 dilakukan bagi pengesahan hubungan pengaruh latar belakang geologi dengan jenis tanah terhadap kadar dos TGR. Berdasarkan maklumat pengkalan data, model regresi linear telah dilakukan bagi meramalkan kadar dos TGR, D_p. Hasil kajian telah mendapati nilai purata tinjauan kadar dos TGR, D_m di lokasi kajian ialah (182 ± 81) nGy j^{-1} dan nilai ini melebihi tiga kali ganda nilai purata global serta dua kali ganda nilai purata di Malaysia dengan julat yang direkodkan ialah daripada 17.4 nGy j^{-1} - 500.0 nGy j^{-1}. Terbitan persamaan model regresi linear bagi jangkaan kadar dos TGR, D_p diberikan oleh D_p = [0.664 D_g + 0.414 D_s - 12.134]. Nilai *p* bagi ujian ANOVA model regresi ialah $p < 0.001$ dengan nisbah - F ($f_{(2, 983)}$ = 2177.0.64) dan nilai korelasi *R* Pearson model ialah $R = 0.903$. Pada aras signifikan 0.05, hipotesis nol ditolak dan dirumuskan bahawa kadar dos D_g dan D_s mempengaruhi nilai D_p dan terdapat korelasi kuat antara latar belakang geologi dan jenis tanah. Bagi pengesahan model dari segi kesahihan statistiknya, data D_m dan D_p telah dianalisis dengan ujian ANOVA dan nisbah F (0.004) yang diperoleh adalah lebih kecil daripada F - kritikal (4.08) dan H_0: $\mu_x = \mu_0$ diterima pada ($f_{cal} \leq f_{1,\ 40,\ 0.05} = 4.08$). Daripada model regresi yang dikemukakan dan tinjauan kadar dos TGR yang dilakukan, hasil data dasar telah diterjemahkan dalam bentuk peta isodos.

ABSTRACT

Terrestrial gamma radiation is one of the main constituents of background radiation and the irradiation is due to the terrestrial radioactivity. Health physics study were carried out to obtain the baseline data of radioactivity and terrestrial gama radiation (TGR) level in State of Selangor, Federal Territories of Kuala Lumpur and Putrajaya. The study provide a methodology of sampling for TGR dose rate survey and a statistical regression model for predicting the TGR dose rate based on linear relationship between total dose rate with geological background, D_g and soil types, D_s. The TGR dose rate survey, D_m has been conducted using scintillation detector Ludlum 19 micro R meter NaI (Tl). Based on airborne survey map, geological background map and soil survey map, the sampling method was used to determine survey point D_m. For quality control of the sensitive TGR dose rates, D_m at environmental level, a statistical interpolation of gradient between calculated dose rate, D_c and D_m have been carried out to obtain the correction factor, C_f using radioactivity data of γ - rays emitters ^{238}U, ^{232}Th and ^{40}K in soil samples. The analysis of radioactivity concentration of radionuclides ^{238}U, ^{232}Th and ^{40}K in soil samples were carried out using coaxial hyper-purity germanium (HPGe) gamma spectrometer. Based on baseline information of TGR dose rate data from previous research (1995 - 2013), 9884 data were analysed using Shapiro - Wilk, Kolgomorov - Smirnov and Levene statistical test for the normality distribution test. For verification of relationships of geological background and soil types on TGR dose rate, statistical hypothesis analysis of Welch's ANOVA and Tamhane T2 were carried out. Based on baseline information, statistical regression model was built to predict TGR dose rates, D_p. The study has found that the average value of TGR, D_m dose rate was (182 ± 81) nGy h^{-1} which is three times higher than global average value and two times higher than average value for Malaysia with measurements range within 17.4 nGy h^{-1} - 500.0 nGy h^{-1}. The derived equation for statistical regression model for predicting the TGR dose rate was given as D_p = [0.664 D_g + 0.414 D_s - 12.134]. The p value of ANOVA regression model analysis was p < 0.001 with F - ratio ($f_{(2, 983)}$ = 2341.053) and Pearson's correlation value R is 0.903. At significant level of 0.05, null hypothesis was rejected and it is concluded that the dose rates of D_g and D_s influenced D_p value and there is a strong correlation between geological background and soil types. For statistical verification of the model validity, D_m and D_p data were analysed using ANOVA test and the F - ratio obtained (0.004) is smaller than F - critical (4.08) and H_0: $\mu_x = \mu_0$ were accepted at ($f_{cal} \leq f_{1,\ 40,\ 0.05}$ = 4.08). Based on obtained regression model and the TGR dose rate survey, the baseline data are presented as an isodose map.

SENARAI KANDUNGAN

SENARAI JADUAL

SENARAI RAJAH

SENARAI SINGKATAN

ANOVA	-	*Analysis of Variance* Analisis Varians
FAO	-	*Food and Agriculture Organization* Pertubuhan Sedunia Makanan dan Pertanian Bangsa-Bangsa Bersatu
GPS	-	*Global Positioning System* Sistem Penentuan Kedudukan Global
IAEA	-	*International Atomic Energy Agency* Agensi Tenaga Atom Antarabangsa
ICRP	-	*International Commission on Radiological Protection* Suruhanjaya Antarabangsa untuk Perlindungan Radiologi
LPTA	-	Lembaga Perlesenan Tenaga Atom
NCRP	-	*National Council on Radiation Protection and Measurements* Dewan Nasional Pengukuran dan Perlindungan Sinaran
NIST	-	*National Institute of Standard in Techology* Institut Piawai dan Teknologi Kebangsaan
SS	-	*Sum of Square* *Hasil tambah kuasa dua*
SPSS	-	*Statistical Package for Social Science* Pakej Statistik untuk Sosial Sains
TENORM	-	*Technologically Enhances Naturally Occurring Radioactive Material* Bahan radioaktif tabii yang dipertingkatkan melalui teknologi
TLD	-	*Thermoluminescent Dosimetry* Dosimeter Termoluminesens
UNSCEAR	-	*United Nations Scientific Committee on the Effect of Atomic Radiation*

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USDA	-	*United States Department of Agriculture* Jabatan Pertanian Amerika Syarikat

SENARAI SIMBOL

A	-	Nombor jisim
$\boldsymbol{b}$	-	Pemalar statistik regressi dos sinaran gama daratan daripada latar belakang geologi dan siri tanah
C	-	Kepekatan radionuklid
C_f	-	Faktor pembetulan
df	-	Darjah kebebasan
D	-	Dos terserap
D_c	-	Kadar dos sinaran gama daratan hasil kajian berasaskan kepekatan ^{238}U, ^{232}Th dan ^{40}K
$\mathrm{D}_{i,j}$		Dos sinaran gama daratan yang diukur daripada latar belakang geologi dan siri tanah
D_m	-	Dos sinar gama daratan yang diukur
D_p	-	Dos sinar gama jangkaan
D_s	-	Dos sinar gama daratan daripada sumbangan jenis tanah
E	-	Tenaga
F	-	Ujian F
G	-	Jenis latarbelakang geologi
G_r	-	Kebarangkalian risiko kanser
H	-	Dos setara
H_a	-	Hipotesis alternatif
H_E	-	Dos berkesan
H_{ex}	-	Indeks bahaya
H_o	-	Hipotesis nul
H_T	-	Dos setara pada tisu/organ
I_γ	-	Aras perwakilan indeks sinar gama
k	-	Jumlah kelompok
M	-	Jisim sampel
n	-	Banyaknya jumlah data

N_o - Jumlah radionuklid asal

N_t - Jumlah radionuklid yang mereput pada masa t

N_α - Bilangan bersih alfa

O - Unsur oksigen

$O.C$ Faktor kependudukan

p - Aras signifikan kebarangkalian

P_γ - Jumlah sinar gama per transformasi nukleus radionuklid

R - Nilai korelasi Pearsons

Ra_{eq} - Indeks kepekatan aktiviti setara radium

$\hat{R}_d$ - Kesan kesihatan radiologi

S - Jenis tanah

t - Masa

$t_{½}$ - Tempoh setengah hayat suatu radionuklid

W_R - Faktor pemberat sinaran

W_T - Faktor pemberat tisu/organ

X - Nukleus induk yang mengalami reputan

Z - Nombor atom

^{232}Th - Unsur torium - 232

^{238}U - Unsur uranium - 238

^{40}K - Unsur kalium - 40

α - Zarah alfa

α^3 - Pekali kepencongan

α^4 - Pekali keruncingan

β - Zarah beta

ε - Kecekapan pengesanan spectrometer gama

λ - Pemalar reputan

σ - Sisihan piawai

$\sigma_{i,j}$ - Sisihan piawai latar belakang geologi dan siri tanah

γ - Sinar gama

μ - Nilai min

$\mu_{i,j}$ - Min dos sinaran gama daratan daripada latar belakang geologi *i* dan siri tanah *j*

SENARAI LAMPIRAN

BAB 1

PENGENALAN

1.1 Latar Belakang

Setiap manusia terdedah kepada pelbagai jenis sumber sinaran mengion sama ada dari sinaran semulajadi (IAEA, 1989) dan buatan manusia (Grasty and LaMarre, 2004). Dedahan sinaran latarbelakang yang diterima manusia adalah wujud secara semulajadi (UNSCEAR, 2000; Achola et. al, 2012) dan merupakan sinaran yang berterusan (Jabbar et. al, 2008) serta tidak dapat dielakkan (Kannan et. al, 2002). Dos tahunan yang diterima manusia akibat dedahan sinaran semulajadi secara puratanya adalah 2.4 mSv (UNSCEAR, 2000). Sumbangan dedahan dos sinaran semulajadi didominasi oleh dua sumber utama (WHO, 1961) iaitu sinar kosmik dari luar angkasaraya dan sinaran gama daratan (ICRU, 2011; Khoshbinfar dan Moghaddam, 2010). Hentaman zarah bertenaga tinggi dari luar angkasaraya dengan elemen nukleus (Poje et. al, 2012) seperti O, N dan Ar yang terkandung dalam lapisan atmosfera akan menghasilkan rantaian interaksi dan produk sekunder (Tokuyama dan Igarashi, 1998) iaitu radionuklid kosmogenik yang memancarkan tenaga sinar kosmik (Vuković et. al, 2007). Dos sinaran gama daratan merupakan salah satu komponen dos sinaran latarbelakang yang diterima manusia (Kapdan, et. al, 2012). Dos dedahan akibat sinaran gama daratan kepada orang awam adalah berpunca daripada radionuklid primordial ^{238}U, ^{232}Th, and ^{40}K (Plant dan Saunders, 1996; Thorne, 2003). Proses nukleosintesis dalam teras bintang telah menghasilkan radionuklid primodial ini (Tzortzis et, al. 2003) yang mana ditemui berselerakan di seluruh tempat di dalam kerak bumi (Quindos, et. al, 1991; UNSCEAR, 2000). Pancaran dedahan sinaran gama daratan berpunca dari jarak 30 cm dalam tanah hingga ke permukaan tanah (UNSCEAR, 2000). Tenaga sinar gama akan diatenuasi oleh ketebalan tanah (Valkovic, 2001) dan selebihnya terpancar keluar sebagai sinaran gama daratan dengan julat tenaga sehingga 2.6 MeV (UNSCEAR, 2000).

Kajian sinaran gama daratan telah banyak dilakukan di kebanyakan negara di seluruh dunia, seperti di Cyprus (Tzortzis, 2003), Austria (Wallova et. al, 2012), Nigeria (Jibiri, 2007), Brunei (Lai, et. al, 1999), Oman (Goddard, 2002), Hong Kong (Tso and Li, 1992), Switzerland (Buchli and Burkart, 1989), Costa Rica (Mora, et. al, 2007), Syria (Aissa dan Jubeli,1997), Sweden (Kock dan Samuelsson, 2011), Rusia (Ramzaev, et. al 2006), Egypt (Ibrahim, et. al, 1993), Lebanon (Samad, et. al, 2013), Pakistan (Tufail, et. al. 2006), Brazil (Yoshimura, et. al, 2004), dan Spain (Quindos, et. al, 1993). Faktor utama kajian ini dilakukan adalah bagi mendapatkan data dasar status aras keradioaktifan dan sinaran tabii sesesuatu lokasi disebut sebagai aras rujukan (Ramli, et. al, 1997) khususnya untuk pelaksanaan akta dan undang-undang kawalan keradioaktifan (García-Talavera et. al, 2011). Kajian sebegini juga menjadi tumpuan khusus dalam mengenal pasti kawasan yang mempunyai aras dos sinaran latarbelakang dan keradioaktifan yang tinggi (Alencar dan Freitas, 2005) bagi tujuan pengkormersialan bahan nadir bumi dan mineral berat (Hu and Kandaiya, 1895; Udompornwirat, 1991 dan Hewson, 1996). Antara kawasan yang dikenalpasti mempunyai bacaan kadar dos sinaran gama daratan yang tinggi ialah di Pantai Guarapari, Brazil - 90, 000 nGy j^{-1}, Ramsar, Iran - 17, 000 nGy j^{-1}, Barat Daya Perancis - 10, 000 nGy j^{-1} (UNSCEAR, 2000), Orissa, India-5000 nGy j^{-1} (Mohanty, et. al, 2004), Kerala, India -3767 nGy j^{-1} (Ramasamy, et. al, 2013), dan New Zealand- 1100 nGy j^{-1} (UNSCEAR, 2000).

Kajian terdahulu oleh (Agocs dan Paton, 1958; Ramli et. al, 1997, 2001, 2003, 2005, 2007, 2009, 2013; Steinháusler dan Lettner, 1992; Tzortzis et, al. 2003; Bituh et. al, 2009; Ateba et. al, 2010; Wagiran et. al, 2013) telah membuktikan terdapat korelasi antara kadar dos sinaran gama daratan, jenis latarbelakang geologi dan jenis tanah. Secara dasarnya, perubahan kadar dos sinaran gama daratan di sesuatu kawasan dipengaruhi oleh jenis batuan geologi (Merdanoĝlu dan Altınsoy, 2006, Momčilović et, al. 2010), jenis tanah (Apriantoro, et. al. 2008; Adayrous et. al, 2010) dan faktor geografi kawasan tersebut (Karahan and Bayulken, 2000; Jibiri, 2001). Batuan igneus jenis intrusif granit secara semulajadinya menyumbangkan dedahan kadar dos sinaran gama yang tinggi (UNSCEAR, 2000) kerana kandungan radionuklid U dan Th yang tinggi di dalam batuan tersebut (Omar et. al, 2006) berbanding batuan endapan dan metamorfik (Tzortzis et, al. 2003) seperti batuan syal dan basalt (Kapdan, et. al, 2012).

Tanah ditakrifkan sebagai siri bahan agregat longgar yang terhasil akibat daripada proses luluhawa semulajadi melalui air, haba dan angin (Strahler, 1987) pada batuan induk dari pelbagai jenis latarbelakang geologi (Plummer et. al, 2007). Hampir 99% tanah di kebanyakan tempat di dunia ini terhasil daripada proses reputan batuan mineral seperti induk igneus (Henry, 1990), batuan metamorfik dan batuan endapan (Jabatan Pertanian Semenanjung Malaysia, 1993). Kelimpahan radionuklid dalam tanah bergantung kepada geologi latarbelakang sesuatu kawasan (Huy and Luyen, 2006). Siri tanah jenis Renggam atau secara saintifiknya dikenali sebagai *Paleudults* (USDA, 1999) merupakan antara siri tanah yang memberikan bacaan kadar dos sinaran gama daratan yang tinggi akibat kandungan uranium dan torium yang tertinggi berbanding jenis tanah gambut (Ramli, et. al, 2003; 2007) yang terhasil akibat daripada proses pereputan tumbuhan dan organisma (Henry, 1990).

Siri tanah Renggam ini terhasil akibat daripada proses pereputan batuan induk jenis granit (Wong, 1970). Ramli et. al, 2003 telah mengemukakan model jangkaan statistik kadar dos berdasarkan pengaruh latarbelakang geologi dan jenis tanah di negeri Johor. Kajian tersebut telah melaporkan pemalar sumbangan kadar dos akibat pengaruh Geo-Soil adalah 50:50. Apriantoro, 2008 dalam kajian radiologi di negeri Perak telah mengemukakan model sama dan mendapati kadar dos sinaran gama daratan disumbangkan oleh 59% dari pengaruh latarbelakang geologi dan 41% dari pengaruh jenis tanah. Model linear regressi yang telah dikemukan ini terbukti sah dan telah diuji keabsahan statistiknya dengan data survei in-situ kadar dos di lapangan. Ujian hipotesis statistik menunjukan tiada perbezaan yang signifikan antara kadar dos yang diukur dan kadar dos yang kira berdasarkan model tersebut.

Dalam konteks perlindungan radiologi alam sekitar, data dasar bagi sesuatu kawasan adalah penting untuk tujuan penilaian status keradioaktifan (Mora et. al, 2007; Papp, 2010) dan sinaran tabii (Ramli et. al, 1997, 2001, 2003, 2005, 2007, 2013). Selain itu, data dasar juga amat bermanfaat bagi tujuan melaksanakan undang-

undang perlindungan dan keselamatan sinaran, polisi dan penguatkuasaan akta yang melibatkan amalan fizik kesihatan (AELB, 1984). Pendokumentasian data dasar aras dos sinaran gama daratan dalam bentuk peta isodos adalah suatu pendekatan yang ideal dan amat berguna. Metodologi ini telah banyak dilaporkan dalam kajian-kajian terdahulu bagi mengemukakan data survei yang melibatkan maklumat geospatial (Agocs dan Paton, 1958; Ramli et. al, 1997, 2003, 2005, 2007, 2013; Steinháusler dan Lettner, 1992; IAEA, 2003; Grasty, R.L. dan LaMarre, J.R. 2004; Ismail et. al, 2005; Dowdall et. al, 2005; Mora, et. al. 2007; Van der Graaf et. al, 2007; Apriantoro, et. al. 2008; Lee et. al, 2009; Ateba et. al, 2010; Khoshbinfar, and Vahabi Moghaddam, 2010; García-Talavera et. al, 2011; Dimovska et. al, 2011; Ruqiang dan Jin, 2012; Kapdan, et. al, 2012; Poje et. al, 2012; Zhao et. al, 2012; Muneer et. al, 2013; dan Caro et. al, 2013).

Kebiasaannya, pemetaan isodos sinaran gama daratan adalah sah sekiranya survei kadar dos di lapangan dilakukan secara intensif. Namun, kajian sebegini akan melibatkan titik survei yang banyak, memerlukan tempoh masa yang panjang dan amat sukar dilaksanakan apabila faktor topografi lokasi kajian menyukarkan seperti hutan tebal, cerun yang curam dalam dan kawasan bergunung. Metodologi persampelan merupakan kaedah statistik yang telah diaplikasi dalam kajian melibatkan survei alam sekitar (Ramli, 2007). Kaedah ini secara saintifiknya dilakukan dengan memilih sebilangan titik persampelan berbanding pemilihan keseluruhan titik populasi pembolehubah (Ramachandran and Tsokos, 2009).

Teknik persampelan rawak (*random sampling*) dikatakan akan mematuhi pola taburan diskriptif statistik sepertimana mengikut populasinya. Persampelan 20 titik survei daripada sejumlah besar titik survei dalam satu-satu populasi akan memberikan hasil keputusan yang sama berdasarkan kepada taburan Gaussian data pembolehubah. Teknik sebegini boleh diuji keabsahan statistiknya berdasarkan ujian kenormalan Kilmogorov-Smirnov (Dowdall et. al, 2005).

1.2 Pernyataan Masalah

Amalan fizik kesihatan khususnya melibatkan kajian sinaran gama daratan dan implikasi radiologi alam sekitar di sesuatu lokasi merupakan suatu kajian dasar yang penting (Kucukomeroglu et. al, 2012) dalam mengemukakan data saintifik aras keradioaktifan dan sinaran tabii semulajadi (Ramli *et. al*, 1997, 2003). Penilaian aras keradioaktifan sinaran tabii penting (Mandić dan Dragović, et. al, 2010) bagi penilaian menyeluruh implikasi radiologi alam sekitar (Reddy et. al, 2003) sekiranya berlaku kemalangan nuklear (Quindos et. al, 1991), amalan nuklear lain yang tidak terkawal seperti kemalangan luruhan nuklear global (Pálsson et. al, 2013; Hamzah et. al, 2012; Ahmad et. al, 2010) dan industri TENORM (Merdanoĝlu dan Altınsoy, 2006; Ateba et. al, 2010). Penilaian peningkatan aras dos sinaran relatif kepada sinaran tabii akibat kemalangan nuklear boleh dibuat berdasarkan kepada aras rujukan sinaran tabii (Mora et. al, 2007).

Di Negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya, mempunyai kepadatan populasi yang tertinggi di Malaysia (Jabatan Perangkaan Malaysia, 2011), oleh itu data dasar mengenai aras keradioaktifan dan sinaran mengion wajarlah diwujudkan. Data dasar yang dikemukan setakat ini hanya melibatkan kajian implikasi radiologi akibat industri TENORM (Hu, et. al, 1981; Chong et. al 1978; Hamzah dan Mahmood, 1985; Meor Sulaiman, 1988; Sharif dan Ghazali, 1987; Udompornwirat, 1991; Roberts, 1995; Hewson, 1996; Omar and Hassan, 2002; Bahari et. al, 2007;; Hu and Kandaiya, 1985a,b; Meor Sulaiman dan Muslimin, 2010; dan Yusof et. al, 2001). Data dasar sebegini tidak menyeluruh dan tidak mencukupi sebagai data dasar. Ia hanya bersifat kajian setempat.

Perkembangan industri TENORM yang pesat (AELB, 1991) khususnya melibatkan aktiviti pemerosesan amang (Hu, *et. al* 1984) dan perlombongan bijih timah (SEATRAD, 1991) merupakan antara penyebab kajian sebegini dilakukan. Latarbelakang geologi dan pemineralan di Timur negeri Selangor (Flinter et. al, 1963) pada Banjaran Titiwangsa (*The Main Granite Range*) merupakan perangsang perkembangan industri TENORM (AELB, 1991) yang boleh meningkatkan aras dos sinaran latarbelakang (Ramli, 2007, Agocs dan Paton, 1958).

Untuk memastikan jaminan sumber tenaga jangka panjang pada alaf baru (Ismail dan Roston, 2012), Malaysia sedang dalam perancangan pembangunan tenaga nuklear (Basri dan Ramli, 2012). Pemilihan tapak loji tenaga nuklear adalah merupakan satu perkara asas yang perlu dipertimbangkan (Basri dan Ramli, 2012). Data dasar status aras keradioaktifan dan sinaran tabii merupakan salah satu keperluan dalam pemilihan tapak loji nuklear (Muneer et. al, 2013).

Penyediaan data dasar aras status keradiokatifan dan sinaran tabii merupakan satu kajian yang mencabar. Survei aras keradioaktifan dan sinaran gama daratan melibatkan beberapa faktor halangan seperti batasan capaian kepada sesuatu lokasi, permukaan topografi hutan tebal tropikal, cerun curam dan melibatkan keluasan yang besar (Ramli et. al, 2013). Satu pembaharuan dari segi metodologi survei aras dos sinaran tabii diperlukan. Kajian ini dilakukan bagi mencadangkan satu metodologi persampelan yang meminimumkan jumlah titik survei. Pengesahan keabsahan dari segi statistik metodologi ini akan menerbitkan satu model regressi jangkaan kadar dos yang akan lebih memudahkan kajian seumpamanya pada masa hadapan.

1.3 Skop Kajian

Kajian ini melibatkan seluruh negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya. Penyelidikan ini meliputi daratan seluas 8,104 km^2 yang mempunyai penduduk yang seramai 7, 209, 175 yang dilaporkan pada tahun 2010 (Department of Statistics, 2011). Kajian ini memberikan tumpuan khusus pada penilaian status aras dos sinar gama daratan berdasarkan dua kaedah berbeza iaitu kaedah survei di lapangan dan kaedah model regressi linear statistikal jangkaan. Teknik persampelan telah digunakan bagi tujuan survei kadar dos sinaran gama daratan di lapangan. Ujian hipotesis statistikal ANOVA telah dilakukan bagi menguji keabsahan model regressi linear jangkaan kadar dos. Pembinaan model ini berdasarkan maklumat pengkalan data yang melibatkan 9884 data in-situ kadar dos sinaran gama daratan di semua negeri di Semenanjung Malaysia, yang dikumpul semenjak 1995-2013 (Ramli dan Jasman, 1995; Ramli et al 1997; 2001; 2003; 2005. ;2007; 2009; 2013 dan Apriantoro, 2008). Ujian hipotesis statistik- *t*, *z*, ujian korelasi Pearson, ujian kenormalan Levene, Shapiro-Wilk, Kolgomorov-Smirnov, dan ujian *Pos Hoc* Tukey's dan Fisher's telah digunakan bagi membuktikan terdapat korelasi yang kuat diantara pengaruh latarbelakang geologi dan jenis tanah terhadap kadar dos sinar gama.

Instrumen pengukuran aras dos sinaran yang digunakan semasa aktiviti di lapangan ialah jenis pengesan sintillasi sinar gama jenis Ludlum 19 $\mu R\ j^{-1}$ (*micro Rontgen per hour*) dan dengan bantuan alat navigasi GPS serta peta topografi semenanjung Malaysia. Setiap pengukuran dos dilakukan satu meter dari tanah iaitu setara paras sistem gonad manusia iaitu sistem genting terhadap sinaran mengion. Bagi tujuan kawalan kualiti kadar dos survei sinaran gama, sebanyak 41 sampel tanah (*top soil*) telah diambil secara rawak di negeri Pahang, Perlis, Kedah, P. Pinang dan Selangor. Analisis kepekatan kandungan ^{238}U, ^{232}Th, and ^{40}K telah dilakukan di Makmal Nuklear, Fakulti Sains dan di Agensi Nuklear Malaysia dengan menggunakan spektrometer gama HPGe. Kaedah kawalan kualiti ini menggunakan teknik interpolasi kecerunan antara pembolehubah kadar dos terkira, D_c daripada analisis kepekatan ^{238}U, ^{232}Th, and ^{40}K dengan pembolehubah kadar dos yang diukur, D_m. Teknik ini digunakan bagi mendapatkan pemalar pekali pembetulan kadar dos, C_f daripada korelasi kecerunan graf pembolehubah.

Hasil data survei yang telah direkodkan dari di lapangan dan hasil kaedah statistikal jangkaan kadar dos sinaran gama daratan akan diterjemahkan dalam bentuk peta isodos dengan menggunakan sofwer Arcgis 9.3. Analisis geospatial kadar dos sinaran gama daratan ini dibina berdasarkan teknik Kriging iaitu satu kaedah interpolasi data secara statistik.

1.4 Objektif Kajian

Objektif kajian ini disusun seperti berikut :-

1. Kajian ini bertujuan untuk menghasilkan data dasar status aras dos sinaran gama daratan semulajadi dan membangunkan satu metodologi persampelan dalam amalan fizik kesihatan serta kaedah statistik model regressi linear jangkaan kadar dos berdasarkan pengaruh ciri geologi dan jenis tanah.di negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya
2. Mengemukakan hasil kajian kesahihan statistik hubungan pengaruh latarbelakang geologi dan jenis tanah terhadap kadar dos sinaran gama daratan.
3. Mengenalpasti kawasan yang mempunyai aras keradioaktifan luar biasa berbanding dengan aras normal global dan aras dos sinaran gama tabii yang tinggi.
4. Menjangkakan risiko impak kesihatan radiologi kepada orang awam.
5. Membina peta isodos sinaran mengion bagi negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya.

1.5 Kepentingan Kajian

1. Menghasilkan kaedah baru bagi penilaian aras dos sinaran gama daratan dengan pendekatan jangkaan statistik dan persampelan yang meminimumkan titik survei dos sinaran gama daratan.
2. Mengemukakan rumusan kesan implikasi radiologi alam sekitar di negeri Selangor berdasarkan data dasar keradioaktifan dan sinaran gama daratan yang telah diperolehi.
3. Mengemukakan data dasar sebagai rujukan untuk kegunaan keselamatan, penguatkuasaan kawalan sisa dan pencemaran radioaktif dari industri TENORM.

4. Memberi maklumat saintifik untuk penilaian impak radiologi dalam situasi genting yang melibatkan kebocoran reaktor nuklear atau pencemaran radioaktif yang meningkatkan aras dos sinaran kepada populasi umum.
5. Data saintifik ini memainkan peranan sebagai bukti dalam hal berkaitan dengan keselamatan amalan sinaran untuk dalam meyakinkan rakyat bahawa negara mempunyai maklumat saintifik mengenai hal tersebut.
6. Bermanfaat bagi tujuan penggubalan dasar dan polisi yang melibatkan keselamatan pekerjaan dan orang awan akibat daripada amalan yang melibatkan penggunaan bahan radioaktif atau tenaga nuklear.
7. Memberikan data tentang kawasan yang mempunyai aras dos sinaran dan tahap keradioaktifan tabii yang tinggi berbanding dengan aras purata dunia dan ini diperlukan dalam proses pemilihan lokasi loji tenaga nuklear.

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